PRACTICAL NOTES

—ON—

HYDROGRAPHIC & MINING SURVEYS,

WITH ILLUSTRATIONS.

—BY—

W. H. HEARDING, C. E.,

ASSISTANT U. S. ENGINEER.

MILWAUKEE:
SENTINEL PRINTING COMPANY.
1872.

PREFACE.

THE following notes on Hydrographic Surveys were written at the request of Brevet Colonel D. C. HOUSTON, Major of Engineers, United States Army, with a view to assist in the equipment of a party going into the field, as well as to explain the method of conducting a survey of that character. Many persons who are theoretically qualified to fulfill the requirements of such a work, may not have had practical experience in the same, and it is possible that the notes may be of service to any such parties as may read them.

The manner of carrying on the instrumental part of the work, which is briefly described, has been found by the writer to be suitable for almost any kind of survey; and particularly in the surveys of mines, upon which subject a short chapter is appended.

If the time of the accomplished officer making the request had not been so fully occupied as to have precluded his writing upon the subject himself, any notes upon the same from his pen would undoubtedly have been more effective and to the purpose.

MILWAUKEE, May 15th, 1872.

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THERE are certain general principles in the science of surveying which are necessary to be observed and practiced in order to obtain satisfactory results.

There are many different methods of making surveys, varying in accordance with the character of the desired information. Each field of operation possesses certain distinctive features which govern the method to be adopted, and the general principles are modified to meet the exigencies of each case. The method prescribed by the United States Government for making the surveys of public lands, and which is admirably adapted to the purpose required, would scarcely be suitable for the determination of the exact metes and bounds of a lot situated in the business centre of a large city; nor would a series of barometrical observations be of much value or assistance in the projection of a working plan or profile of a railroad, although they might be sufficiently accurate for determining the approximate heights of a mountain range.

Hydrographic surveys are conducted upon the same general principles as those upon land; the chief difference in the mode of procedure is occasioned by the fact, that in one case the contour of the earth's surface above the water level is obtained by means of instruments, which are designed and constructed for the purpose, in the other, its inequalities are determined by direct measurement from the natural level of the water surface.

In order to delineate the contour and express the character of a lake or river bed with accuracy, it is obviously necessary to take a larger number of measurements than are usually required above the water surface; as in the latter case the most prominent features are exposed to view, and their characters and extent are readily assailed and determined; while in the former, objects which may lie hidden by the water, and which would be serious obstructions to navigation, or impediments to a contemplated improvement, may escape detection through a lack of a sufficiency of measurements or soundings; and although it may be assumed, from the general appearance and character of a shore in the vicinity of a survey, that a lake or river bed is probably even and free from obstructions, and will not require minute examination, such assumption cannot be acted upon without endangering the truthfulness of the description portrayed by a plat of the survey.

The properties and construction of instruments, and the methods of using them; the mode of recording such angles and data as are necessary to effect a complete and proper survey, differ in accordance with the views and education of the person making the survey.

In linear surveys for Railroads, most engineers record the forward angles as being so many degrees and minutes to the right or left (as the case may be) of the previous tangent, and plat their work with the aid of a protractor. The surveyor of public lands denotes the magnetic bearings and distances of certain described witness trees from the quarter or section posts, so that their positions can be readily identified at any future time.

As a general rule it is expected that a surveyor will effect his work in about one-half the time which should be occupied in performing it, and which would be extended to any other character of work of equal importance. This fact appears the more strange when all the bearings and contingencies depending upon a survey are duly considered. It is more than probable, that if a sufficient time had been allowed for deciding the proper and most economical route to be pursued, many railroad companies would have saved expensive cuttings and embankments, sharp curves and heavy grades, as well as a superabundant weight of iron. The celerity of action demanded may perhaps be attributable to an urgent necessity for laying the track at the earliest possible moment, so that a company may be reimbursed for its outlay through the sale

of lands granted for the purpose, the title to which can only be secured by the completion of a portion, or the whole of the road; or perhaps it is required by the terms of its charter to be finished in a specified time. Such considerations are not always satisfactory or agreeable to either the surveyor or the company.

These notes are written with a view to assist persons who are theoretically qualified to conduct a survey. and who may also have had practical experience in the use of instruments, and made surveys for railroads, etc., but who may not have been called upon to plan and conduct a hydrographic survey. The notes will therefore be confined to the description of methods used in making surveys of Lake or River Harbors.

As such surveys are generally preliminaries to artificial improvements, it may be well at this starting point to impress upon the mind the necessity for including in a survey, all objects which may affect the work of improvement, so that they can be correctly depicted upon a plat of the same; for as the plat is the basis upon which the constructing engineer depends when making his estimates of the cost of a proposed work, any inaccuracies or omissions which may occur in its projection, will tend to an erroneous estimate of the approximate cost of the undertaking.

Some little method and consideration are necessary to the equipment of a party for making such a survey as we have under consideration, so that when the field of operations is reached, delay shall not be occasioned through lack of such instruments and materials as are necessary to commence and prosecute the work successfully. The first requisite is a suitable theodolite or transit instrument, graduated to 360 degrees, a careful examination of which should be made before leaving for the field, and in case any of its parts require adjustment or repairs, they should be thoroughly made, and the instrument be put in good working order. Next see that it is fixed firmly and carefully in its box, leaving the clamp screw to the upper limb loosened; arranging and padding the whole so that none of its parts shall be jammed or bruised in its transportation. It should be entrusted to one of the party in whom confidence can be placed, and who is sensible of the necessity of transporting it with care. If the instrument is supplied with hair appendages for estimating distances by means of what is termed a stadia, a line should be carefully selected and measured, and the stadia rod tested

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at precisely equal distances in feet on the line, to the limit of the range of the instrument between the horizontal hairs. By means of the vertical circle necessarily attached to the instrument, the positions and distances of interpolation points, the elevations and depressions of the ground, can be determined with great facility and approximate accuracy. If the theodolite is not provided with these appendages, it will be necessary in most surveys to use a leveling instrument and rod; the adjustments of this instrument should also be examined, and, if necessary, corrected. Equal care must be taken in the transportation of this instrument.

A correct chain of fifty feet in length, and eleven pins, are the next requisites.

A Chesterman's metallic tape-line should be provided, for the convenience of measuring to any points of interpolation when sketching the details of topography.

A stout chest of about 3¼ feet in length, 2¼ in width, and between 1¼ and 1½ feet in height, provided with suitable lock, key and handles, is required for the transportation of articles of equipment.

Procure a small bull's-eye lantern, and a phial of olive oil for use when taking an observation for true meridian; it is well also to take a small quantity of watch or almond oil, in case the instruments should require to be cleaned during the time of making a survey. In cleaning a tarnished graduated limb of an instrument, the end of the finger should be used, as dust often collects in chamois leather or silk, and also the harshness of the leather will scratch and mar the lines of graduation.

Take as many field note books as will be necessary to contain all the records of the survey. The left hand page of these books is generally ruled in columns, the first of which, on the left hand side of the page, being used to record the names or numbers of stations, and objects observed through the instrument; in the second, the Alpha vernier readings of the instrument are stated; in the third, the readings of the Beta vernier; in the fourth, the mean values of angles; in the fifth, sixth, etc., magnetic, or stadia readings, or the true courses of lines, etc., are noted. The right hand page is ruled with blue lines, and divided up into squares of about one-quarter inch sides. On this page the details of the topography are sketched; the squares represent one chain's length, or fifty feet

each. The central line of the page is red, and is generally adopted and used to represent the line of measurement, which commences at or near the bottom of the page. Two or more *courses* are frequently sketched on one page; the length of each course is recorded opposite the point of its termination; the numbers, or names of the stations between which the line is measured are properly affixed at each end of the line. If more than one course is sketched upon a page, and if the divergence of the second from the first is large, a portion of the topography near to the end of the first course should be duplicated, as the change in the direction of the second course from the first, will change the positions of objects to the vertical lines on the page, in proportion to the divergence of the second course from the first. The termini of courses should be represented at proportional distances between the horizontal lines, corresponding to the fractional parts of the last chain measured upon the course. The next course should commence on the next horizontal line above the terminus of the first, and so on. If any of the topographical features can be delineated more readily and distinctly by sketching two or three courses upon a page, in connection with and in their relative positions to each other; the squares on the page will not be serviceable beyond the limit of the course which is represented by the red line.

The foregoing explanation of the character and use of note books has caused a digression from the subject of outfit.

To determine the true meridian, it will be necessary to copy into one of the note books, from the Nautical Almanac, a series of the declinations of Alpha Ursæ Minoris (Polaris), extending over the length of time which will in all probability be required to effect the survey; also the time of the greatest eastern or western elongations of that star during the same period. The approximate latitude of the point of survey should also be obtained and recorded in the same note book, the accuracy of which can be closely determined at the time the observation is made, by reading the angle of elevation of the star upon the graduated vertical circle attached to the instrument.

In the selection of lead pencils for use in sketching topography and recording soundings, it is best to take rather a hard quality of lead, for if it is of a very soft nature, too much time is expended in

keeping the point of the pencil sharp. Faber's No. 5 are good pencils for such purpose.

Next procure and pack in the chest such drawing instruments as are required to make a rough plat of the field, viz: A pair of spring, and a pair of pencil dividers, a suitable ruler, and triangles; a protractor; scales of equal parts; drawing pens; paper tacks; a few sheets of double elephant or cartridge paper; a yard or two of tracing vellum; india ink; mouth glue, or mucilage; rubber, and paper for use in making computations; a copy of logarithmic and trigonometric tables will be necessary for this purpose. Each day's work should be computed and plotted as it progresses, so that if any data of importance has been omitted, or only imperfectly obtained, it may be secured or corrected during the succeeding day's field work.

A good row boat is indispensable; for a small party it should be built about twenty-three feet long; five feet centre beam, with roomy stern sheets and full bow; when not used for sounding, the bow oarsman to be seated upon the grating, which should be large enough to admit of a leadsman standing upon it with ease; it should not be too crank, but have a good bearing upon the water, should be steered with a tiller, and furnished with five row-locks and oars, two boat hooks, foot braces, dipper, sponge and painter to complete her equipment.

A sounding rod twenty feet in length, carefully graduated to feet and tenths, is the next necessary article to be used in sounding to a depth of eighteen feet of water; if soundings should be carried to a greater depth, a lead line pricked to fathoms and half fathoms must be used. A lead of nine pounds weight, is sufficiently heavy for use in water which is not more than eight fathoms deep. Before using a new lead line, it must be thoroughly stretched, so that the expansions and contractions shall be reduced to a minimum. To effect this, fasten one end of the line securely to a smooth-barked tree, or a round pile, and wind the line regularly and tightly around it when dry; having firmly secured the other end, dash on water until it is thoroughly saturated, and leave it until it is again dry, then tighten the line by winding it around as before, and again dash on water. By repeating this process several times, the line will be ready to be spaced off into fathoms and half fathoms,

at which distances it is pricked with a marlin spike, and suitable tags of leather, which are numbered, are inserted through the holes.

Stations should be erected at the extremities of all the prominent points to be included in a survey; in the bights of bays, and at such other positions as are necessary to be occupied and used for triangulation and sounding purposes. They should be constructed of durable timber (cedar is the best wood for this purpose), with centre posts of from 3½ to 4 feet long, and set into the ground about 2½ to 3 feet. Bore an auger hole into the centre of each post for the reception of a straight flag-pole, which is the object to be observed to in the performance of the survey; an auger two inches in diameter is the best size to procure for this and other purposes; the pole when inserted into the hole can either be wedged, or braced, in such a manner as to keep it in a vertical position. This post or station is termed a point of observation, and the theodolite is centered directly over the hole. The top of such a post as described would be about a foot above the surface of the ground, and the tripod of the instrument could be readily placed over it, and the instrument centered. If a trivet or crow-foot is provided for the instrument, as is usual in making trigonometrical surveys, or for astronomical purposes, the center posts must necessarily be cut of a greater length, and the height of the top of the post above the ground, or the platform upon which the observer stands, should be about four feet. In this case, it would be necessary to cut the post about seven feet in length, to observe when standing upon the surface of the ground. In case the head of a pile or the decking of a substantial dock should be used for a point of observation, the auger-hole will remain as a permanent mark for future identification. The centre poles of the stations should be numbered with Roman numerals up to ten; commencing again with one for the eleventh station, two for the twelfth, etc. Split shingles, or old barrel staves, will answer for this purpose very well. They should be nailed to the centre pole, as near as convenient to the top. The number of the station should also be cut, or marked upon the post with red chalk. The principal observation, or triangle stations, should be capped with flags. To attach the flags and slats to the poles, nails and tacks will be required, as also a hammer, light axe, hand-saw and spade, in the general work of constructing stations, etc. To make the stations as conspicuous as

possible, a coating of whitewash should be given them; this will involve the necessity of procuring a sufficiency of lime, a pail, and whitewash brush. As well as nails, a few spikes should also be taken in the chest.

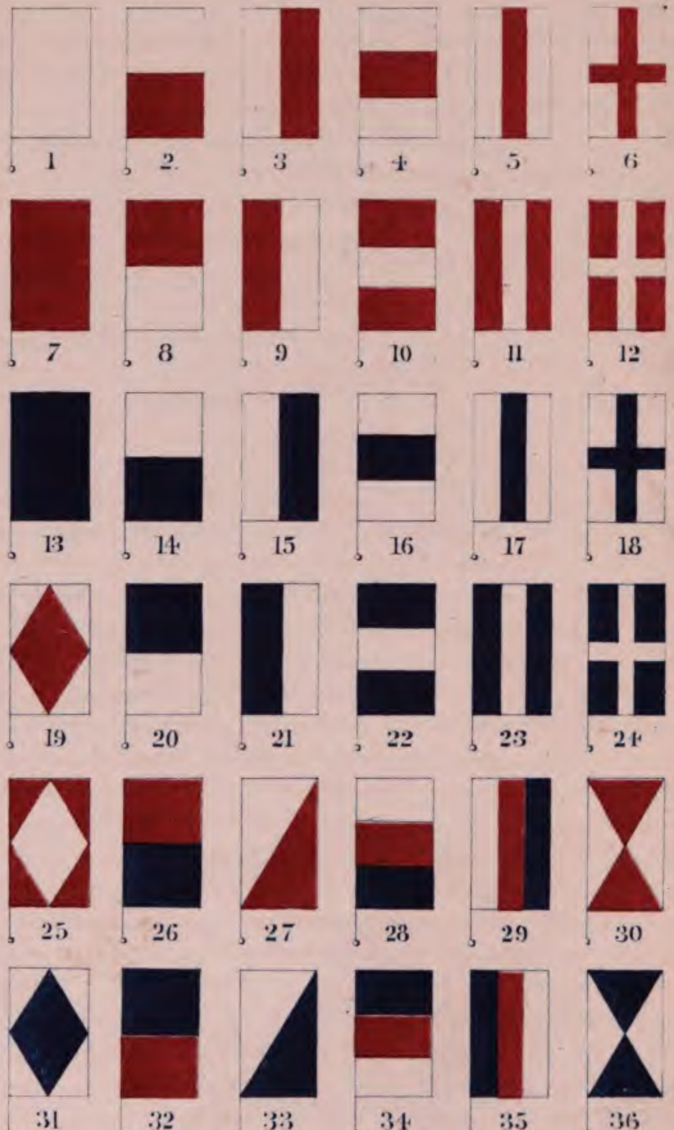
Buoys should be made of cedar, or other light wood, the floats twenty inches long, and eight in diameter, tapering at the lower end; a hole to be bored through the centre with a two-inch auger, through which a flag pole is run of about thirteen feet in length; the pole is firmly fastened in the float by means of wedges; the stock or lower end of the pole should project eighteen inches below the float; through this stock, which is somewhat flattened at the butt, a hole is bored with a ⅝ inch auger, and the rope which connects the buoy with its anchor is threaded through the hole, and fastened at the required length. Tarred rope, known as buoy rope, is used for this purpose, and must be provided for the buoys.

To save the expense of procuring and transporting iron disks or anchors, rocks weighing about forty pounds each, are strapped with rope, and a net-work or mousing of marlin is interwoven with the straps, to prevent them from slipping off the rocks. The flags which are attached to the top of the buoy poles, for the purpose of designating them, should be of different devices, so that mistakes shall not occur in the record of observations or soundings. White, red, and dark blue or black, are the best colors to use for this purpose. They should be made before going into the field, and kept in the chest when not required for use; a few yards of cotton cloth should also be supplied, to attach to the principal triangulation, or flag stations on shore. (See the system of devices for buoy flags on next page.)

If the lines of sounding are of such lengths as to render the stations and buoys indistinct, or indiscernable with the naked eye, when at either end of the line, a good field-glass, or telescope must be provided. An instrument of this kind is almost always needed in making a survey of any kind.

These notes being written chiefly in explanation of the method of conducting surveys of harbors above a perceptible tide-water, it will not be necessary to obtain data in relation to lunar influences; but as the annual changes in the height of fresh water bodies are

Designs for Buoy Flags



sometimes great, the stage of the water in the locality of a contemplated survey, should be ascertained from reliable authority before commencing the work.

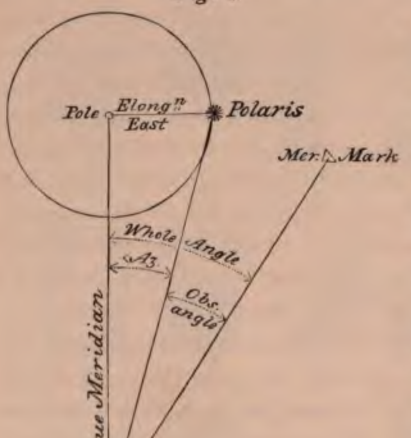
Having enumerated most of the preparatory essentials, we will suppose that we are in the field.

The establishment of a bench mark in reference to the line of high or low water, should receive the first attention; from this mark, any fluctuations in the height of the water can be determined, and should be recorded at least three times during each day, of the survey, and oftener, if there are grounds for supposing that the variations are great during the time occupied in taking soundings. All subsequent examinations of the harbor should be referred to this mark, and all soundings should be reduced to its plane of reference. It should be established upon some conspicuous and permanent object, so that it can at any time be readily found and identified. A large spike or bolt, in the face of a pier is a good mark, care being taken to record its bearing and distance from some other witness point, marked upon the door-sill of a substantial house, or other more permanent structure, or natural object, noting carefully the difference of level between the bench mark, and witness point. The next thing to be done, is to select a base of operations; this may be either a continuous straight line, which is the best, if it can be obtained; but if the field should not admit of the measurement of a suitable line in one continuous course, two or more lines may be used, and the whole length of the broken base computed after the work is traversed. The line, or lines, composing the base, should be carefully measured at least twice or more, both forwards and backwards. If the base is broken, or more than one line is used, the angle or angles included between the lines, should be carefully measured by a repetition of observations. The ground selected for the measurement of a base, should be as nearly level as it is possible to obtain, in order to secure a correct horizontal measurement. In extensive surveys where great accuracy is required, base lines are measured with properly seasoned wooden rods upon a rope alignment, or with compensating metallic bars; but as our survey is not supposed to be very extensive, and as we are only equipped with a chain, it is not necessary here to discuss these methods of measurement.

The next thing in order should be the setting up of a meridian

post or station, from which to observe astronomically. It should be placed in a position where no object will intervene, or intercept a view of Polaris, and also from which some of the principal points of the survey are visible; then set up a substantial meridian mark, with a surface large enough to centre a lantern upon, and at the time of observation see that the light is placed over its centre point. (In the list of articles previously stated as requisites, the lantern is not enumerated, for the reason that in a settled country such an article can readily be obtained for the purpose.) A narrow slit cut through a piece of card-board or shingle, which can be nailed to the post upon which the lantern is set, on the side nearest to the observation station, shades the glare of the light; and the instrument is directed to the light shining through the slit, which in this case is the meridian mark. It is best to set this mark at a convenient point, either a few degrees to the eastward or westward of north, as observed from the observation post. In the annexed illustration (Fig. 1) it will be seen that the observation is supposed to be taken when the star is at its greatest eastern elongation, and as the meridian mark is shown as being placed to the eastward of north, it is evident that the distance of the star from the true meridian, must be added to the angle observed between Polaris and the meridan mark, to obtain the true course from the observation post to the meridian mark.

Fig. 1.



A more thorough elucidation of the methods usually practiced in making surveys of this character, can perhaps be given by selecting some of the notes of a survey which has actually been made, and copying them from the note books as they were recorded in the field, and also by making a copy of a plat of the same for reference, introducing from time to time such explanations as are thought to be necessary.

A survey of the mouth of Two Rivers, Wisconsin, will be suitable for this purpose. The notes upon the first page of the note book are as follows:

AUGUST 19th, 1870.

Observation taken on Polaris to determine the true Meridian.
Greatest Eastern Elongation of the Star.

AT OBSERVATION STATION.

	A	*B*		
To Mer. Mark,	360° 00′ 00″	180° 00′ 00″		
To Polaris, .	6° 39′ 40″	186° 39′ 40″	< altitude =	Lat. 44° 04′ 30″

Greatest Eastern elongation at 9 hs., 19 min.

Declination of Polaris at date of observation, 88° 36′ 50″.

Latitude of Observation Post, 44° 04′ 30″

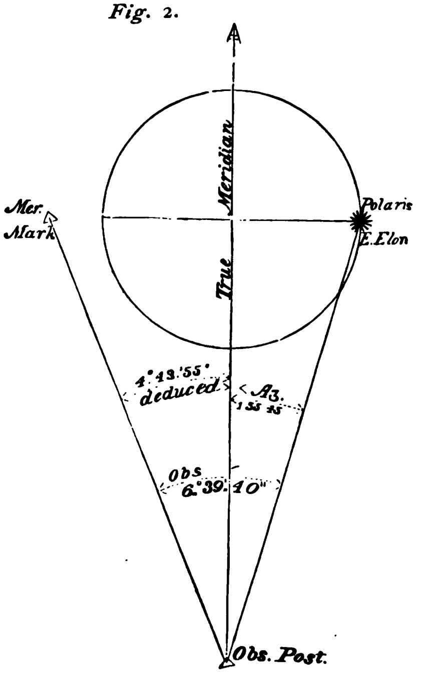
A simple form for computing the azimuth of the star is as follows:

$$\frac{\text{Cos. Dec.}}{\text{Cos. Lat.}} = \text{Sine Aximuth.}$$

Therefore,

Log. Cos. Dec...88° 36′ 50″..8.3836330
Log. Cos. Lat...44° 04′ 30″..9.8563844
Log. Sine Az.... 1° 55′ 45″..8.5272486

Fig. 2.



The limb of the instrument used, being graduated from the right towards the left, then the observed angle between the meridian mark and Polaris, - - 6° 39′ 40″

Minus the Azimuth of Polaris at its greatest eastern elongation................ 1° 55′ 45″

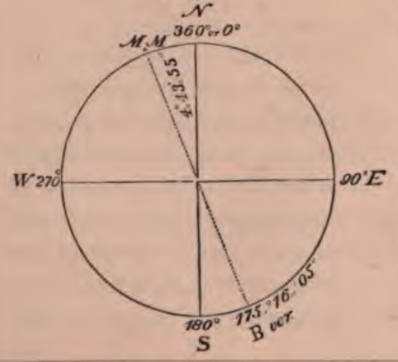
Gives the true bearing of meridian mark from observation post............N. 4° 43′ 55″ W.

In this case the meridian mark was set to the westward of north, as observed from the station. The observation was taken when the star was at its greatest eastern elongation, or at its farthest distance east from the true meridian; consequently the angle at the

observation post, between the star and the true north, equal to $1^\circ\ 55'\ 45''$, as above obtained, was deducted from the observed angle of $6^\circ\ 39'\ 40''$, by reason of the meridian mark having been placed to the westward of north, as observed from the station. If the mark had been placed to the eastward of the meridian, of course the azimuth angle must have been added instead of being subtracted, as before described by Fig 1.

It is not absolutely essential to the accuracy of a survey in itself, that it should be plotted in reference to the true meridian, but as in all surveys the angles and lines measured and computed, must be platted in their proper relations and positions in reference to each other, it is always desirable that they should be so laid down, and particularly in the plat of the survey of a harbor, where the bearings of piers and improvements, are used by masters of steamers and sailing vessels, to govern their approach to it. Independent of these considerations, in the projection of a plan for the improvement of a harbor, it may be essential to consult meteorological records for advice as regards the direction of the prevailing winds, etc., in the vicinity of a contemplated improvement, and form a plan which will modify or counteract any prejudicial effects, which the physical formation of the locality may present, either from littoral currents, erosions of the shore, heavy seas, etc., induced through the prevalence of the wind from certain quarters. These considerations, and others which will readily suggest themselves, are sufficient evidence as to the propriety of conducting and platting a survey in reference to the true meridian. The graduations on the limb of the instrument used in making the survey which we have under consideration, were numbered from right to left, as before stated, and as shown by Fig. 3. By referring to the notes it will be seen that the true bearing of the meridian mark from the observation post was N. $4^\circ\ 43'\ 55''$ W. By subtracting that angle from 360°, the reading of the left hand or Alpha vernier, upon the graduated limb of the instrument is obtained, which is

Fig. 3.



355° 16′ 05″. The reading of the right hand or Beta vernier is therefore 175° 16′ 05″. In order to keep the telescope, together with the zero point of the instrument, upon the true meridian throughout a survey, the reading of the Beta vernier as read when observing at (say) Station No. 1 to Station No. 2, must be used for the reading of the Alpha vernier, when at Station No. 2, and observing to Station No. 1. Thus, when at the observation station, and observing to the meridian mark, the reading of the Alpha vernier was 355° 16′ 05″, and the Beta 175° 16′ 05′; by transferring the instrument to the meridian mark, and setting it up, clamping the instrument with the Alpha vernier reading, 175° 16′ 05″, and consequently the Beta vernier reading 355° 16′ 05″, the telescope of the instrument must point to the true meridian, if its upper limb is unclamped, and turned until the reading of the Alpha vernier is 360° 00′ 00″, or zero. In other words which perhaps will be more comprehensive, knowing the true bearing of the line from the observation station to the meridian mark to be N. 4° 43′ 55″ W., the bearing of the same line is reversed to S. 4° 43′ 55″ E., when taken from the meridian mark to the observation station.

By referring to the plat, it will be seen that Buoys Nos. 3, 4, 5, 6, 8 and 7 were placed out in range with each other, on the line of about twenty-three feet of water; and Buoys Nos. 11, 2 and 9 on range, in line with the face of the end of the east bridge pier. Buoys are usually platted by the aid of a protractor from the angles which have been observed at stations upon shore. One of the reasons therefore, for placing them out on range, is, that any instrumental error may be at once detected through the plat; another is, for the detection of any change which may have been occasioned to their positions through storms, or other influences during the progress of the survey, between the time of placing them out, and that at which the angles of observation were taken with the instrument; such ranges are also useful in defining any desired intermediate points upon a line of soundings, or the extremities of such lines as it may be desirable to run from the shore, etc.

The positions occupied by the stations, and reference bench mark, as well as those of the lines of base, and ranges for lines of sounding to be run upon, are also shown upon the plat.

To return to an examination of the note book. Upon Page No. 2, the following observations are recorded:

AT OBSERVATION STATION.

	A	*B*				
To Mer. Mark,	355° 16′ 00″	175° 15′ 40″				
Bearing of Wash'g'n St.	359° 19′ 00″	179° 18′ 00″				
△ D Old Mill	189° 24′ 00″	9° 24′ 00″				

SELECTED READINGS AT △ D, OLD MILL.

	A	*B*	Mean Angles.	True Courses Deduced from Readings.	Obs. Distances by Stadia Feet.	Vertical Angles
To Obs. Sta..	9° 24′ 00″	189° 24′ 00″		N 9° 24′ 00″ E		
Ch. Spire...	11° 44′ 00″	191° 44′ 20″		N 11° 44′ 10″ E		
Triangle △ F	48° 54′ 20″	228° 54′ 00″		N 48° 54′ 10″ E		
Sound'g ⊙ 1.	57° 34′ 00″	237° 34′ 20″		N 57° 34′ 10″ E		
⊙ 2.	58° 30′ 00″	238° 30′ 20″		N 58° 30′ 10″ E		
⊙ 3.	60° 05′ 00″	240° 05′ 00″		N 60° 05′ 00″ E		
⊙ 4.	59° 06′ 40″	239° 07′ 00″		N 59° 06′ 50″ E		
⊙ 5.....	50° 54′ 00″	230° 54′ 00″		N 50° 54′ 00″ E		
⊙ 13 ?..	133° 25′ 00″					
△ B....	149° 05′ 20″	329° 05′ 40″	149° 05′ 30″	S 30° 54′ 20″ E cor.		
⊙ 7.....	195° 52′ 00″			S 15° 52′ 00″ W		
⊙ 8.....	219° 27′ 40″			S 39° 27′ 40″ W		
⊙ 9.....	230° 05′ 00″			S 50° 05′ 00″ W		
△ A....	225° 39′ 20″	45° 39′ 40″	225° 39′ 30″	S 45° 39′ 30″ W cor.		
Chair Factory	313° 49′ 40″	133° 50′ 20″		N 46° 10′ 00″ W		
Pail Factory..	324° 32′ 00″	144° 33′ 00″		N 35° 28′ 30″ W		
Stake 17......	320° 52′ 30″			N 39° 07′ 30″ W		

Selected Readings at D, Old Mill, Continued.

	A	B	Mean Angles.	True Courses deduced from Readings.	Obs. Distances by Stadia Feet.	Vertical Angles
" 15......	321° 09′ 00″			N 38° 51′ 00″ W		
" 24......	327° 44′ 00″	147° 44′ 00″		N 32° 16′ 00″ W	724	—3° 10′
" 22......	327° 13′ 00″			N 32° 47′ 00″ W	372	—5° 57′
Buoys 1 and 9.	106° 22′ 00″					
Buoy 2.......	94° 10′ 00					
△ C, Flag Pole on Mann's Dock............	151° 23′ 40″	331° 24′ 00″	151° 23′ 50″	S 28° 36′ 10″ E		

It will be observed that there is sometimes a difference of as much as twenty seconds in the recorded readings of the Alpha and Beta verniers; this is particularly noticeable when the readings have been taken with great care; the difference is attributable to the eccentricity of the instrument, but it does not seriously impair or invalidate the correctness of the work, as a mean value of the angles is taken; and when making a careful triangulation, it is customary to repeat and read the angles until the whole of the limb has been included and covered by the repetitions, and the mean value is determined from the readings around the whole circle. Sometimes the number of seconds is not recorded at all; in such cases, the objects observed to are of secondary importance, as far as the location of them to the fractional parts of a foot is concerned; the reading of an angle to a buoy for instance, and recording the same to seconds, would be a work of supererogation, as it is not at all probable that a buoy will remain precisely in the same position, during the period of time occupied in transporting an instrument from one station to another; the buoy anchor will, or should be, stationary, but the buoy itself is liable to swing with either a current of water, or wind setting from any direction, to a distance which would involve several minutes of arc, unless the lines of sight, or radii are of great length; also such objects as are here termed secondary in importance, being usually plotted by the aid of a protractor, and their positions determined by lines of intersection

geometrically projected from the principal points of observation, the positions of which are accurately computed, it is evident that it would be superfluous to measure angles to such objects as close as to seconds, inasmuch as the thickness of either of the lines of intersection, would cover a larger space on the plat than is occupied by seconds of arc. The following notes of observations are selected from those recorded as

TAKEN AT △ A.

	A	*B*	Mean Angles.	Distances.
To △ D.......	45° 39′ 30″	225° 39′ 30″	45° 39′ 30″	
△ B.......	67° 54′ 10″	247° 54′ 30″	67° 54′ 20″	
△ C Flag-pole on Mann's Dock.	103° 17′ 20″	283° 17′ 20″	103° 17′ 20″	
⊙ 7............	72° 15′ 00″	252° 15′		
⊙. 8............	79° 39′	259° 38′		
⊙ 's 9 and 10...	248° 19′	68° 19′		
St. 13, back r'nge	325° 26	145° 26′		Mea. 205′
Buoy 5..........	111° 10′			
" 6.........	122° 13			
" 7.........	186° 15′			
△ D..........	45° 40′ 00″	225° 40′ 00″		

AT △ B.

	A	*B*	Mean Angles.
To △ D......	329° 05′ 30″	149° 05′ 40″	329° 05′ 35″
△ A......	247° 53′ 30″	67° 54′ 00″	247° 53′ 45″
△ C......	152° 33′ 00″	332° 33′ 40″	152° 33′ 20″
⊙ 6........	27° 23′	207° 23	
B. 7.........	206° 04′		
" 8........	194° 40′		
⊙ 13 Approx...	125° 48′		
△ D..........	329° 04′ 40″	149° 05′ 20″	329° 05′ 00″

The foregoing instrumental readings have been purposely selected from the recorded notes, for the reason that the angles **A. B. D** form one of the triangles included in the survey, and the line **A-B** is also the measured base used in the system of triangulation covering the work. The conditions of this triangle are not as good as could have been desired; for no angle in a computed triangle should be less than thirty degrees. It is desirable that each of the triangles comprised in a system should be as nearly equilateral as possible; this rule should he particularly observed in surveys which embrace an extensive district of country, for in such extended surveys, the sides of triangles are often expanded and increased to great lengths by computation from short measured bases; any error, therefore, which is introduced through an imperfect measurement of the angles, is increased in proportion to the rate and extent of the expansion of the sides.

In the case of the triangle which has been introduced for the purpose of illustration, it must have been impracticable to obtain better conditions on account of the unfavorable conformation of the ground, or the obstructive properties of its topographical features.

Points of triangulation are carefully computed and used as checks upon intermediate work, the bearings and distances of the lines involved in which work are surveyed in their proper relations to each other between the points of triangulation; one of the points being that of the commencement of the intermediate work; the other being the terminus of the section of the field which the subsidiary lines cover between the points. The secondary lines are each of them bases to which the topographical sketches, etc., are referred.

Having computed the positions of the triangle points, first correctly from the main base, and subsequently through the system of secondary lines; if it should be found that a discrepancy exists between the co-ordinates deduced through the computations, a proper correction must be made in those obtained through the system of secondary lines which have been run and connected with and between both points of triangulation.

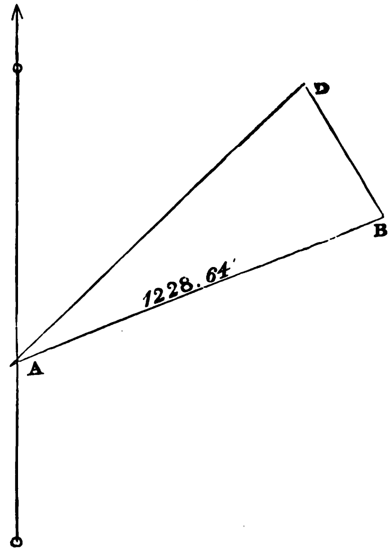
The angles comprised in the triangle, as taken from the foregoing notes, are as follows:

At △ A.	At △ B.	At △ D.
To △ B, 67° 54′ 20″	To △ D, 329° 05′ 35″	To △ A, 225° 39′ 30″
To △ D, 45° 39′ 30″	To △ A, 247° 53′ 45″	To △ B, 149° 05′ 30″
Obs. angles, 22° 14′ 50″	81° 11′ 50″	76° 34′ 00″

Angles as taken from Notes.	Corrected Angles.
< A, 22° 14′ 50″	< A, 22° 14′ 40″
< B, 81° 11′ 50″	< B, 81° 11′ 30″
< D, 76° 34′ 00″	< D, 76° 33′ 50″
180° 00′ 40″ = 40″ excess.	180° 00′ 00″

Corrections of angles should be carefully made; duly considering the probabilities of error at each station; as to whether the observations were taken at either of the stations during an unfavorable state of the atmosphere, or from indistinctness of the stations observed, etc. Sometimes, in very hot or cold weather, an instrument will not work as freely as is usual during a temperate degree of heat, through the expansion or contraction of the metal of which the instrument is constructed. Notes as to the probable quality of the observations taken, should be recorded at the time the angles are observed, as such information frequently assists in the decision as to which angle or angles correction is most proper to be made.

Fig. 4.



Method of Computation by Logarithms.

Sin < D,	76°33'50",	9.9879475
	Ar. Com.	0.0120525
Sin < A,	22°14'40",	9.5781334
A—B,	1228.64,	3.0894247
D—B,	478.20,	2.6796106
Sin < D,	76°33'50",	0.0120525 Ar. Com.
Sin < B,	81°11'30",	9.9948475
A—B,	1228.64,	3.0894247
A—D,	1248.31,	3.0963247

The courses or bearings of the sides of the triangle are next determined. By referring to the recorded observations taken at △ D, it will be seen that the instrument was set up upon the true meridian as before described, (*i. e.*) with the telescope directed to the centre of the observation station, and with the Alpha vernier set to read 9° 24' 00", which was the reading of the Beta vernier when observing to △ D from the observation station. In the same series of observations taken at △ D, the mean value of the recorded readings of the instrument when directed to △ A was 225° 39' 30". The course or bearing, therefore, of A from D is S. 45° 39' 30" W., as it is that number of degrees and minutes more than 180° (or south) upon the limb of the instrument (see Fig. 3). And inversely,

From	A to D is	N. 45° 39' 30"	E.
Corrected	< at A is	22° 14' 40"	+
Making	A-B	N. 67° 54' 10"	E.
Then	B-A	S. 67° 54' 10"	W.
Corrected	< at B,	81° 11' 30"	+
		149° 05' 40"	
Deduct from, -	-	180° 00' 00"	
Gives B-D,	-	N. 30° 54' 20"	W.

In this description △ A is taken for the initial point of the survey, to which all the other computed points are referred in traversing the work. The co-ordinates, or latitudes and longitudes of all those points are deduced and referred to that station. What is termed traversing the work is nothing more than the computation of a series of right-angled triangles, in each of which the bearing and length of the hypothenuse is given to find the base and perpendicular. The computation is made as follows:

△ A — △ B.

Course, N. 67° 54′ 10″ E.
Length, 1228.64 feet.

DEPARTURE EAST.		LATITUDE NORTH.	
Log. Sine, -	9.9668673	Log. Cosine, -	9.5753950
Log. Distance,	3.0894247	Log. Distance,	3.0894247
1138.37,	3.0562920	462.19	2.6648197

△ A — △ D.

Course, N. 45° 39′ 30″ E.
Length, 1248.31 feet.

DEPARTURE EAST.		LATITUDE NORTH.	
Sine, - -	9.8544182	Cosine, - -	9.8444371
Log., - -	3.0963247	Log., - -	3.0963247
892.78,	2.9507429	872.49,	2.9407618

△ D — △ B.

Course, S. 30° 54′ 20″ E.
Length, 478.20 feet.

DEPARTURE EAST.		LATITUDE SOUTH.	
Sine, - -	9.7105753	Cosine, - -	9.9334949
Log., - -	2.6796106	Log., - -	2.6796106
245.59,	2.3901859	410.30,	2.6131055

Having thus obtained the latitude and departure in feet of D from A; also of B from A, the deduction of the co-ordinates in reference to the initial point A, and the accuracy of the computations involved is tested as follows:

A = ZERO.				ZERO.
From A; B is	N 462.19	and	E 1138.37	
" " D is	N 872.49	"	E 892.78	
" D; B is	S 410.30	"	E 245.59	
So that from A; B is	N 462.19	"	E 1138.37	

We thus see that the computations are correct, and that all such computed points can be platted without the aid of a protractor. By a continuation of this method of additions and subtractions of latitudes and departures, to or from any point whose position has been thus determined from the initial station, the reference to the initial can be carried forward *ad libitum;* and in case the length and direction of a line is required between any two of the points thus determined, which are not visible from each other, it can be obtained by formula

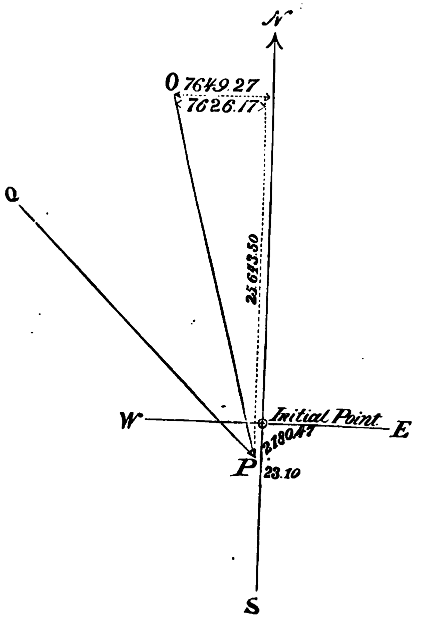
$$\frac{\text{Dep.}}{\text{Lat.}} = \text{Tangent of Bearing,}$$

and we then have given, the two sides, and two of the angles of a right-angled triangle to find the remainder.

In illustration we will suppose two stations, P and O, to be invisible from each other, and the co-ordinates

Of △ O to be, - -	N. 25,643.50 ft.	W. 7,649.27 ft.
Of P to be, - -	S. 2,180.47 ft.	W. 23.10 ft.
Relative position of O from P =	N. 27,823.97 ft.	W. 7,626.17 ft.

Fig. 5.



Now, O being to the northward of the initial point, and P to the southward, the latitudes as derived from the initial point are additive; and as both of the stations have west longitudes, the lesser longitude of P is subtractive.

By the above formula,

Log of Departure,	7,626.17,	3.8823065
Log of Latitude,	27,823.97,	4.4444191
Tangent Bearing,	15° 19′ 39″	9.4378874

Then, by setting up the instrument at P, and observing to some visible station (as Q), whose true bearing is known to be (say) N. 45° 00′ 00″ W., and with the Alpha vernier consequently reading 315° 00′ 00″, by turning the upper limb until the Alpha vernier reads 344° 40′ 21″, the telescope will point in the direction of Station O.

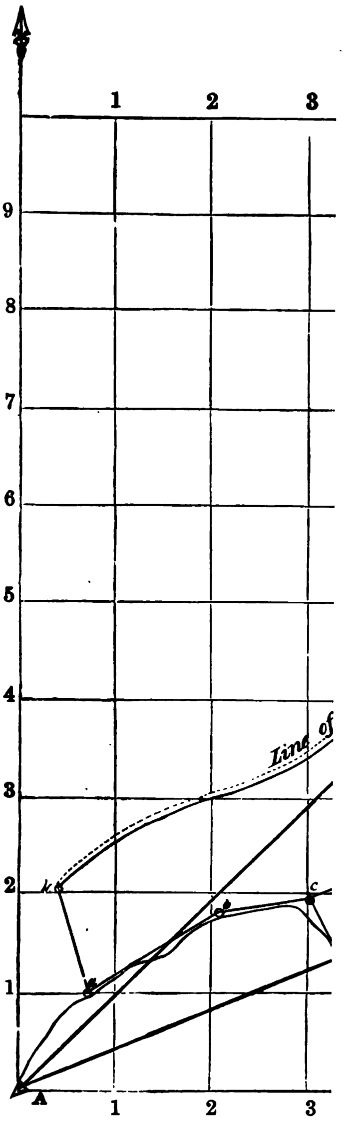
The course and consequent angle of P to O being N. 15° 19′ 39″ W.

Being subtracted from - - -	90° 00′ 00″
Gives the angle O, - - - - -	74° 40′ 21″

And the length of the line O-P can be computed from this data.

If a large area of ground had been comprised within the boundaries of the triangle A, B, D., which would have necessitated the measurements of a number of angles and lines in the delineation of the topographical sketches, all the measurements must have been referred in such case to one of the lines and its terminal points, in order to verify the accuracy of the intermediate work; and to do this, each of the intermediate lines between the two points must necessarily have been traversed by the method before described. To illustrate the system more fully, it is assumed that the distances between the stations were thousands instead of hundreds of feet, and the latitudes and departures of the intermediate points were in their relations to △ A the initial point, as stated in the following table of co-ordinates of stations and stakes:

Names of Stations and Stakes.	Latitudes.	Departures.	
△ A............	zero.	zero.	
△ B............	N. 4621.90	E. 11,383.70	
△ D............	N. 8724.90	E. 8,927.80	
Stake *a*..........	N. 1002.20	E. 760.20	
" *b*..........	N. 1804.32	E. 2,080.46	
" *c*..........	N. 1985.61	E. 3,011.58	
⊙ 1..............	N. 993.43	E. 3,587.21	
Stake *d*..........	N. 2603.14	E. 4,803.14	
" *e*..........	N. 2741.06	E. 6,008.10	
⊙ 3..............	N. 1153.12	E. 6,879.49	
Stake *f*..........	N. 3187.45	E. 7,112.56	
" *g*..........	N. 3276.80	E 8,881.07	
" *h*..........	N. 7631.09	E. 8,950.14	
" *i*..........	N. 4859.20	E. 4,817.26	
" *k*..........	N. 2001.00	E. 412.17	



II

WITH THE STATIONS AN

It will readily be seen that the co-ordinates of △ **B**, deduced directly from △ **A** by means of the triangle **A. B. D.** are an excellent check upon the intermediate work executed between, and connected with both stations, and that by measuring the courses and distances of lines A–*a*, *a–b*, *b–c*, etc., and closing the work at **B**, through the same system of traversing, any error in the measurements of the intermediate angles or lines will be at once detected, and if a large error is discovered, the work must be re-examined on the ground. If but a small error is found to exist, which may be attributable to the manipulation of the instrument, or to measurements which have been made over uneven ground, the co-ordinates of the points involved in the intermediate work must be proportionally corrected, and made to correspond with those of △ **B** as deduced by triangulation. It is also evident that any errors are avoided which might be introduced to a plat through the mechanical defects of a protractor, or through an unskilful use of such instrument; (and in which case the errors would be carried through the whole of the subsequent work platted) by computing the co-ordinates of the several points of the survey, and platting them by means of the system of squares above described; for if, through want of experience or practice, the draughtsman should not plat one of the several points in its exact position, the remainder of the points would not be involved in the mistake.

The magnetic variation of the needle is not laid down upon the accompanying map, but to illustrate the method by which it is determined it is assumed that readings of the compass were taken

At △ **A**.

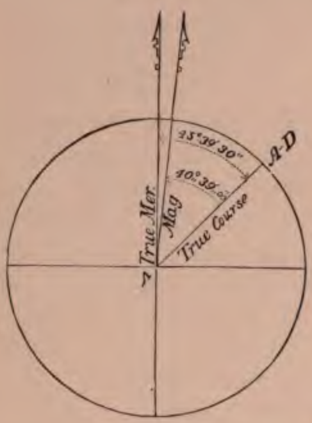
Stations.	North End of Needle.	South End of Needle.	Mean Values.
To △ **B**........	N. 62° 55′ E.	S. 63° 00′ W.	N. 62° 57′ 30″ E.
" △ **D**........	N. 40° 40′ E.	S. 40° 30′ W.	N. 40° 35′ 00″ E.

The true course of line **A–B**, determined by astronomical observation, is - - - - - N. 67° 54′ 10″ E.
And the mean value of the Magnetic Observation is - N. 62° 57′ 30″ E.

The difference between the Magnetic and True course, 4° 56′ 40″

The true course of line A-D is - - -	N. 45° 39′ 30″ E.
The Mag. " " " - - - -	N. 40° 35′ 00″ E.
The difference in the courses to D is - -	5° 04′ 30″
The difference in the courses to B being - -	4° 56′ 40″
	2) 10° 01′ 10″
The mean difference between Mag. and True courses,	5° 00′ 35″

Fig. 7.



Then, to determine whether the magnetic variation is east or west, by Fig. 7 it will be seen that the true course from A-D, which is a fixed line, is N. 45° 39′ 30″ E., and that the magnetic course is but N. 40° 39′ E.

The magnetic course therefore, being less than that of the true course, shows the magnetic meridian to be to the eastward of the true meridian by 5° 00′ 35″, which quantity is the mean value of the differences determined; or the magnetic variation is 5° 00′ 35″ east at △ A. For, as the true line A-D is a fixed number of degrees and minutes as determined by astronomical observation from the true meridian, and the angle subtended between the magnetic line of meridian and the fixed line A-D being less than the true angle, by applying the magnetic line to the true line as a proper base, and describing the included arc back towards the north, the sector inscribed between the true line A-D and the true meridian will not be covered by that as obtained through the needle by 5° 00′ 35″ of arc.

If the stadia is used to obtain the contour of the ground, the horizontal distances, and difference of level are determined from readings taken with the instrument upon the stadia rod, and the angles of elevation or depression which are read upon the vertical circle of the instrument. In the notes recorded as taken at D, the distance from that station to Stake 24 is 724 feet by stadia, and the angle of depression 3° 10′. By referring to tables which have

been recently published to facilitate the work of obtaining the horizontal distances, and differences of level, through the use of the stadia, the vertical height of the instrument at △ D, above Stake 24, is found to be 39.89 feet; and the horizontal distance from D to 24 equal to 722.17 feet. These tables are arranged and used in a similar manner to that of taking the latitudes and departures of courses and distances from a traverse table; correction being made for the focal distance of the object glass of the instrument; the verticality of the rod, and other quantities, according to formulæ deduced by Professor S. W. Robinson, of the University of Michigan. As a description of this method of taking levels and making surveys would be too voluminous to include in these notes, reference can be made to the publication above referred to by those interested.

In recording the observations made with a spirit level, the following simple method has been found satisfactory. The height of the instrument has not been introduced. The columns on the left hand page of the book are used to record the observations, and the heights obtained therefrom ; on the right hand page, the points upon which the rod was held are designated.

Stations.	Back Sights.	Fore Sights.	Rise.	Fall.	Total Heights.
					Feet.
1	.391				50.00
		1.406		1.015	48.985
		9.375		8.984	41.016
		3.015		2.624	47.376
2	5.804				47.376
		6.591		0.787	46.589
		8.729		2.925	44 451
		10.816		5.012	42.364
		2.368	3.436		50.812
3	10.356				50.812
		0.743	9.613		60.425
4	9.656				60.425
		0.585	9.071		69.496
5	10.079				69.496
		0.813	9.266		78.762

As shown by the plat of the survey, the buoys were placed out in range with each other, the outer line being in about twenty-three feet of water ; between the range lines, the water was of such a

depth as not to require very minute examination, and the method adopted for sounding that portion of the work was that which is usually practiced in making extensive surveys, viz: by running lines from one buoy to another, crossing each other at different points; a good general idea of the depth of the water, and character of the bottom can be obtained by a net-work of lines run in this

REMARKS.

Nail Head, Door-sill of Co's Office (above Datum 50 Feet.)

Observation Post, near Office.

Nail in Launder; Outlet of Pond (at water surface).

Stake U 1.

" " "

B. M. on Boiler House (Foundation of Chimney), marked 300—3.411.

Rod on East Rail of Road, under Trestle Work, to Furnace.

St. R. 2.

B. M. on Stump.

" " " "

Peg Marked B. M.

" " " "

St. Side of Road.

" " " "

St. near Pit No. 1.

manner. To effect this properly, the boat must be brought up to the point of starting, and the depth of the water taken and recorded, with the bow of the boat pointed in the direction of the line to be

run. If the starting point is at one of the outer buoys, some distinct object upon the shore which is in range with the buoy to which the line is to be run, must be kept in the same range during the whole length of the line. A skillful steersman can do this without difficulty, provided the water is not too rough to admit of the taking of accurate soundings, even if a current should have a tendency to drift the boat from a straight line, and it should be necessary also to steer the boat with its bow pointing in an oblique direction to the direct course of the line. The speed of the boat while sounding, must not be accelerated or diminished during the whole length of a line, as the soundings are taken by time; for if a change is made in the rate of speed, the spaces between soundings will not be equal, and a proper correction for such change of rate cannot be made when platting the spaces upon the map. Where the water is from ten to twenty feet in depth, an expert leadsman can take soundings every quarter minute; in less than ten feet, they can be taken with ease every ten seconds. A line of soundings taken by this method is recorded as shown in the margin, and in platting them the line is divided into as many spaces as the soundings taken, less one; the last space occupying but twenty seconds of time, is of course but two-thirds of the distance occupied by each of the other spaces upon the plat. Those platted on the west side of the map were taken by means of ranges placed on shore. A line was established two hundred feet back of, or to the northward of Base A-B, and parallel with it; range flags were planted on these lines, at measured distances of one hundred feet from each other, commencing at △ B and St. 1; 2 and 2; 3 and 3, etc. The boat was taken to the outer range of buoys, and the first sounding was taken at the point where the line of the buoy range was intersected by the flag range of △ B and St. 1 back, upon which range the boat was kept until the shore was reached.

B. 4—B. 2.

At Buoy, 23 feet. (Sand.)

¼ Minutes.	21.8	"
	21.2	"
	20.8	"
	20.8	"
	20	"
	19.2	"
	19	"
	18.5	"
	18	"
	17.1	"
	17.1	"
	16.7	"
20 Seconds.	15.7	"
	15 at Buoy 2.	

The notes taken when sounding this line are shown in the margin.

{ Line on range of △ B with St. 1, commencing at outer range of buoys.

	23.3	at outer range.
½ Min.	22 3	(Sand.)
	20.7	"
	17.7	"
¼ Min.	15.6 (Rod.)	Sand.
	15.1	(Sand.)
	14.4	"
	13.8	"
	13.2	on line face of dock.
	12.5	(Sand.)
	11.2	"
	10.6	"
	10.2	"
	9.1	"
	8.2	"
	7.4	"
	6.2	"
	4.6	"
	3.8	"
	2.8	"
	2.3	"
	2.5	"
7 Sec.	1.0	at shore.

The boat was not steered properly when running the next line recorded in the note book, from Stakes 2 and 2 to outer range of buoys, and the records were discarded. The line was sounded over again, commencing at the outer range as before, and running to the shore upon range of Flags 2 and 2. At any point upon a line of sounding where two objects which are located by the instrument are in range with each other, such range should be carefully noted, for it will be of assistance when spacing off the distances which have been run by the boat between soundings. The third minute sounding of 13.2 feet was taken upon the line of the face of the dock, as will be seen by referring to the recorded line. Having run the line on flag range 2 and 2, from the outer buoy range to the shore, the flagman took up the flags, and planted them at range stakes 3 and 3, and the line of soundings was commenced as near the shore as practicable upon that range, and carried to the outer range of buoys, the distance from the shore to the first sounding being estimated as nearly as possible. The remainder of the lines covering this section of the work were sounded in the same manner, being governed by the flag ranges upon shore.

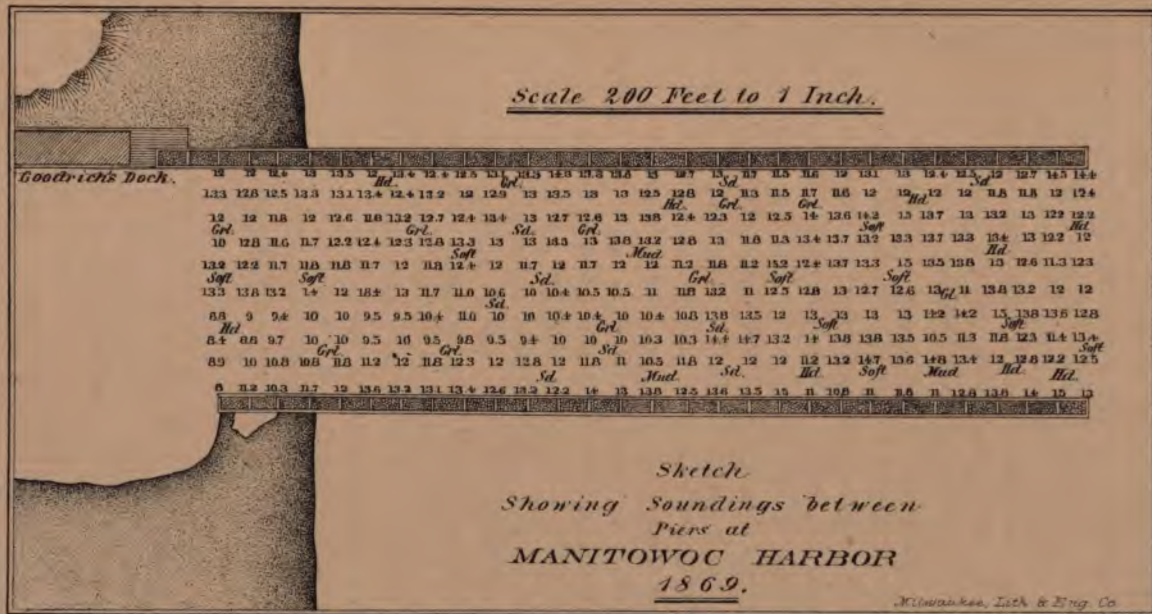
Where the shore line is rocky, or the water so shallow as to prevent a boat from approaching into a close proximity with a station or starting point located upon shore, it is best to place out and locate a buoy, or a flag stake firmly driven, which will not be removed by the sea, in water of a sufficient depth to float and maneuvre the boat for the proper starting point of a line desired to be run, as a correct estimate of distances made with the eye

between two points, can only be acquired by constant practice after long experience.

The lead line should be tested occasionally during each day's sounding, and if any change in its length is found through its contraction, the error must be recorded in the note book, and a proper correction of the records of the depth of water made. In changing the spaces of time between soundings, care should be taken to make such changes at the records of even half minutes or minutes, in order to avoid confusion when platting the work. Soundings were taken over the northeast portion of the work upon lines governed by flag ranges which were established upon the piers at distances of fifty feet from each other, in the same manner as before described. The ranges of buoys with each other were noted as they occurred upon the lines of sounding run when making the described survey; and it is a matter of the first importance, that such buoy and station ranges be recorded whenever they are observed to occur; for the rate of speed at which the boat is propelled may be imperceptibly changed during the process of sounding a line, through the agency of light winds or currents, and a line produced on the range of two objects which are included in a survey, and carefully platted upon a map of the same, is practically equivalent to a reading upon an instrument, and the point where such a produced line intersects with a line of soundings will "cut off" or divide the line into sections, so that the spaces between soundings can be laid off more correctly upon each section of the line.

The soundings in the branches of the river were taken by time; but a much better method of sounding out a narrow channel, is to stretch a line across it at specified distances on shore, which can be accurately platted in their proper relations to any of the stations or objects included in the survey; the soundings to be then taken at measured distances marked upon the stretched line; by this method accurate cross sections can be obtained. The sketch of the channel between the piers at Manitowoc harbor, showing the soundings, will illustrate this method more clearly than a written description. (See sketch.)

Another excellent method of taking soundings, which, if performed with care, insures a correct exhibition of the contour of a lake or river bed, is by using two instruments, set up at suitable


Scale 200 Feet to 1 Inch.
Goodrich's Dock.
Sketch
Showing Soundings between
Piers at
MANITOWOC HARBOR
1869.
Milwaukee, Lith & Eng. Co.

stations for securing proper angles of intersection over the section of field to be sounded, and made at regular stated intervals of time, as may be agreed upon by the observers and the person taking the soundings. To effect the work by this method, the time indicated by the watches of the observers and the person taking the notes of the soundings must be set together previous to its commencement, and if the watches are not properly rated, the time must be verified and the watches corrected, as soon as any great variation in time is discovered. A signal is made by the time-keeper in the boat, who elevates a flag at a period of five seconds before the time of sounding, at which time it is again lowered. Angles are taken by the observers between some of the stations or objects included in the survey, and the sounding rod, or some fixed object attached to the boat, as may be agreed upon. A skilful observer can take the angles and record them once every minute with ease. By this method the exact position of the boat can be determined at every fourth sounding, when the intervals of time are fifteen seconds between soundings; so that if the boat is not steered upon a straight course, the accuracy of the survey is not seriously affected thereby. It is best, however, to run the boat systematically upon lines as straight as practicable, for the reason that the field is better covered by doing so, than if the soundings are taken promiscuously, and also the points of beginning and ending of lines can be defined more readily by the observers on shore. Although the services of more persons are required to effect a survey by this method, and the use of two instruments is also required, such services are amply compensated for by the time which is saved, and the accuracy with which the work can be done, for it is not necessary to place out more than three buoys on range with each other, at the outer limit of the field as a boundary line.

Whenever and wherever it is practicable, the simplest and best method is to take soundings through the ice; it is particularly so where great exactness is required, inasmuch as the whole work can be done by actual measurement, and a better opportunity is afforded for a thorough investigation of the character of the bed; and also in this case, each sounding is taken at an established stationary point, whereas if taken from a boat which is in motion, the same precision cannot be attained. An hydrographic survey by this method, becomes practically the same as a survey on land; for

a system of squares, or other figures can be laid out upon the ice to govern the sounding, as readily as the beds of a garden plot. If the ice is thick, a chisel beveled to an edge from both sides is the best instrument with which to cut the holes.

In the survey of a harbor upon the sea coast, it will be necessary to set up a tide gauge, the zero point of which must be placed in reference to the plane of mean low water, at which a careful observer must be stationed during the time of taking soundings, who will record the heights of water at intervals of five minutes, so that the soundings taken can be correctly reduced to the plane of mean low water. The parties also taking the soundings must record the time of the beginning and ending of each line of soundings run, and at intervals of five minutes corresponding with those of the observer at the tide guage, will note the time opposite to the soundings taken at such intervals. The times of high and low water occurring during the several phases of the moon will be found in the table of the establishment of the port, in which tide table the differences of rise and fall are given for each day of the lunar month. The tide gauge may either be a long rod or post graduated to feet and tenths, and firmly fixed to some permanent object, with the zero point placed at mean low water level; or a suitable float with a rod attached may be encased in a box of the required length, which is perforated with holes of one-quarter inch diameter at the bottom for the admission of the water; the inside dimensions of the box to be large enough to admit of the rise and fall of the float freely.

In this case the graduations on the rod are made to coincide with the mean low water level, or are made in reference to a bench mark, the height of which has been determined by observation, the zero point being opposite to the index when the float is at mean low water.

In case the area to be included in the survey is large, and should embrace the mouth of a river, or an estuary or frith, it may be necessary to establish sevèral tide gauges as above described, at different points of the survey, for if the conformation of the shore is such as to confine the tidal currents within narrow, and perhaps tortuous limits, a curved surface may thus be imparted to the water

in the place of a horizontal surface. In some localities a gauge may be made or formed by setting on line a series of benches or posts firmly driven into the beach, so as to be capable of resisting the action of the waves, and extending from mean low, to high water mark; the whole of which will in reality form one gauge divided into stages or steps, the lowest graduation on the lowest post of which will be the zero point of the gauge, and must correspond with the zero points upon the other gauges used in making the survey, so that all of them shall be referred to the same plane of mean low water. The distribution of these gauges will be governed by the best judgment of the person in charge of the survey. In illustration we will assume that we have run a line of soundings, and that the following observations and notes have been recorded:

——— HARBOR, MARCH 28th, 1872.

OBSERVATIONS OF TIDE GUAGE.

TIME.	Height in feet above low water mark.
Ho. Min., A. M.	
8 : 10	6 . 4
8 : 15	6 . 2
8 : 20	5 · 9
8 : 25	5 · 6

——— HARBOR, MARCH 28th, 1872.

SOUNDINGS ON LINE POSITION 1—POSITION 2.

TIME.			Soundings reduced to plane of mean low water.
Ho. Min., A. M.		Feet.	Feet.
8 : 14	At P. 1,	28	21 . 8
8 : 15		27 Sand.	20 . 8
		25 "	18 . 8
		26 "	20 . 0
		22 Mud.	16 . 0
		20 "	14 . 1
8 : 20		19 "	13 . 1
	½ Min.	19½ "	13 . 6
		19 Sand.	13 . 1
		20 "	14 . 2
		18 "	12 . 2
		17½ "	11 . 8
		17 "	11 . 3
		17¾ "	12 . 1
	¼ Min.	18 at P. 2.	12 . 4 at P. 2.

In this character of survey the left hand side of the page is used for recording the soundings as they are taken; the column on the right hand side is left blank, to be used in the reduction of the soundings to mean low water level by means of the observations upon the tide gauge. In the above illustration it is assumed that the first sounding at Position 1 was taken at 8 ho., 14 min., and that the actual depth of the water at that time and place was 28 feet; but by referring to the observations at the tide gauge it will be seen that the water was 6.2 feet above mean low water level at the nearest observation to that time (8 ho., 15 min.); this quantity is there-

fore deducted from the actual depth recorded to find the correct depth of water at Position 1 below mean low water. The positions of the boat, or the points of sounding, should be determined by the use of two instruments set up at shore stations as before described, as the points can be determined more accurately by this method than it is possible to obtain them through the use of the sextant. If the establishment of the port has not been previously effected, it will then be necessary to determine the planes of high and low water, and their means by a series of observations taken carefully once every ten minutes upon a tide gauge set up as described and in reference to a bench mark, and extending over a period of time of not less than three lunar months in duration, and if the time and circumstances will admit, such observations should extend over a period of six lunar months previous to the commencement of a survey, which will include the observations over the highest equinoctial tides.

As soon as a survey is completed, the lake or river bed should be probed at such points as excavation is necessary to a contemplated improvement, so that a complete and just exhibition can be made of the character of the material to be removed. A sharp-pointed steel rod is a good instrument to use for this purpose where the required excavation is deep and the material hard. If the cutting is light or shallow, and of a loose character, an auger-bit, fitted and brazed into gas-pipe, is serviceable, as a portion of the material can be withdrawn by it for inspection.

The improvement proposed to be made at the harbor of Two Rivers is, first, by constructing protection piers of pile work—one of 400 feet in length or more, on the east side of the river channel; the other of about 600 feet in length on the west side of the entrance, as circumstances may justify. By this means a sand accretion will probably form outside of the piers, and by the excavation of a channel from the line of six feet of water in the lake, to the deeper water of the river, a channel can be kept open during the construction of a more permanent work formed of cribs inside of the protection piers.

The described method of performing the instrumental portion of the work in making surveys of harbors, is also applicable to other kinds of surveys; and particularly so to the surveys of mines (in which kind of work the writer has had quite an extensive experience), or to other interests where great accuracy is required; for it

is evident that a plat of any survey can be laid down by this method more correctly than it can be made through the use of a protractor; and also the co-ordinates of points being determined in their proper relations to each other, the direction between the ends of drifts or galleries can readily be computed as described, and the connections made with exactness, provided the levels have been carried on correctly in reference to making such connections.

Also in defining a boundary line through woodland property, by starting from a section or quarter-section post and running in the general direction of the desired line, selecting for courses such lines as are clearest of underbrush, or present the least obstacles to a correct measurement, and making the point at the extremity of the boundary line to be defined the terminal point of the last course, the exact course of the line to be cut can be computed as before described, using the line of the first course as an assumed meridian for such purpose. A great saving of labor in hewing timber can often be made by the adoption of this method.

SURVEYS OF MINES.

THE method before described, viz: by traversing the lines and computing the co-ordinates of the points involved in the survey of a mine, is the most correct method of doing the work.

An underground survey, is to all intents and purposes, the same as one which is made upon the surface. The chief difference in the mode of procedure arises from the fact, that in the case of a surface survey, the instrument used is centered *over* the different points involved in the survey, which are selected as being necessary to a proper exhibition of the work; while in the performance of an underground survey the instrument is generally centered *under* the different points selected for use in the drifts, or galleries, which are first cut and opened, and which form the connections between the working shafts. Some of the principal difficulties to be encountered are, the getting proper lines of sight to the several levels or galleries in connection with the points involved in the surface survey; the difficulty of illuminating the telescope, so that the cross hairs of the instrument can be centered correctly upon the line of the plumb-bob, which necessarily must be used; the correct reading of the instrument by the aid of an artificial light; the care which is required in constructing a platform across a shaft; the selection, of an intelligent assistant who will place the light to be observed to in a proper position; the patience which is necessary to be practiced both by the surveyor and the miners, during the necessary detention of the work of blasting; as also the exercise of the same virtue, when waiting for the clearance of a shaft or drift from smoke, or in cold weather, from the steam arising through a condensation of the warmer atmosphere of the mine, commixing with the colder atmosphere of the external air; the keeping of a clean note book when the artificial light used is that given by a tallow candle; or when muddy water percolates through the fissures of the surface

rock; the measuring correctly down a shaft, from the axis of the instrument to the point observed by the instrument; and many other details which are incident to this particular character of survey.

Having designated the method by which a survey should be made, it may be well to make a few notes upon the method which should be practiced in the opening up of mines, inasmuch as the proper manner for the commencement of such an enterprise depends upon a correct plat of the property, the resources of which are proposed to be developed.

If the geological structure of the crust of the earth which is embraced in the section to be so treated, has been upheaved by subterranean or volcanic forces, and the different strata of which it is composed have been examined by exploration, and a proper exhibition of the thickness and character of each distinct formation has been satisfactorily proved, and a working vein has been decided upon; the first operation to be performed should be to sink trial pits along the line of the lode, at about such distances apart as will in all probability be necessary to the most economical and effective working of the mine in its subsequent development.*

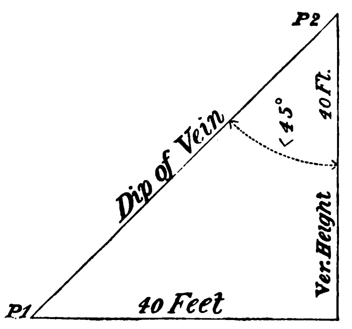
The vein or lode sought for having been found, two or three of the trial pits should be sunk to such a depth as will determine the dip of the formation, and define distinctly the upper and lower (or the hanging and foot) walls of the vein, as they are designated, so that the points of contact of both the upper and lower strata can also be positively determined, and show the width of the lode. Then, if the surface of the ground is upon a perfectly horizontal plane, two stakes, or marks, set up at the two extreme points of exposure at the junction of either the hanging or foot wall (which are respectively the strata above and below the vein), will define the general direction of the lode across the section. But where the

* An exploration of a piece of property is usually made by cutting trenches (at right angles as near as practicable) across the general formation of the district, at such points as the deposit of alluvium is the thinnest or shallowest, selecting such lines for operation as can be most easily drained on the surface; it may not be possible on account of the undulating character of the surface, to denude the whole series of strata by the cutting of a single trench, by reason of an influx of water; if such should be the case, the work of denudation must be taken up at a corresponding jointure of the stratification on some other portion of the property where the surface is capable of being drained, so that the character of the whole can be disclosed.

crust has been subjected to the influence of such subterranean forces, as to have been tilted from its original horizontal position in the manner described, the fractured strata seldom present a horizontal surface, but as is more probable, will be left in a broken, rough, uneven condition, and the difference of levels upon the line of the lode may be large. In such case the marks set up at the extreme exposed points, will not indicate the true course of the vein, by reason of the dip or inclination of the formation, but the actual course can be determined by computing the angle, which is subtended by the base of a horizontal right-angled triangle, whose perpendicular is equal to the base of a similar vertical right-angled triangle, and which base is therefore common to both the horizontal and vertical triangles, and can be computed from the parts given, viz: the angle of the dip of the formation, and the difference of the levels between the two points.

As a simple illustration, we will suppose that a vein runs in a direction from S. W. towards N. E. The dip of the formation is towards the N. W., at an angle from the vertical of 45 degrees, the level of the vein at its jointure with the hanging wall at P 1 is zero, and at the corresponding jointure at P 2 it is 40 feet of vertical height, the distance between the two points being 350 feet; it is evident that the base of the triangle involved will be 40 feet, or equal to the perpendicular height, and the true course of the vein upon a horizontal plane can be computed as follows:

Fig. 8.

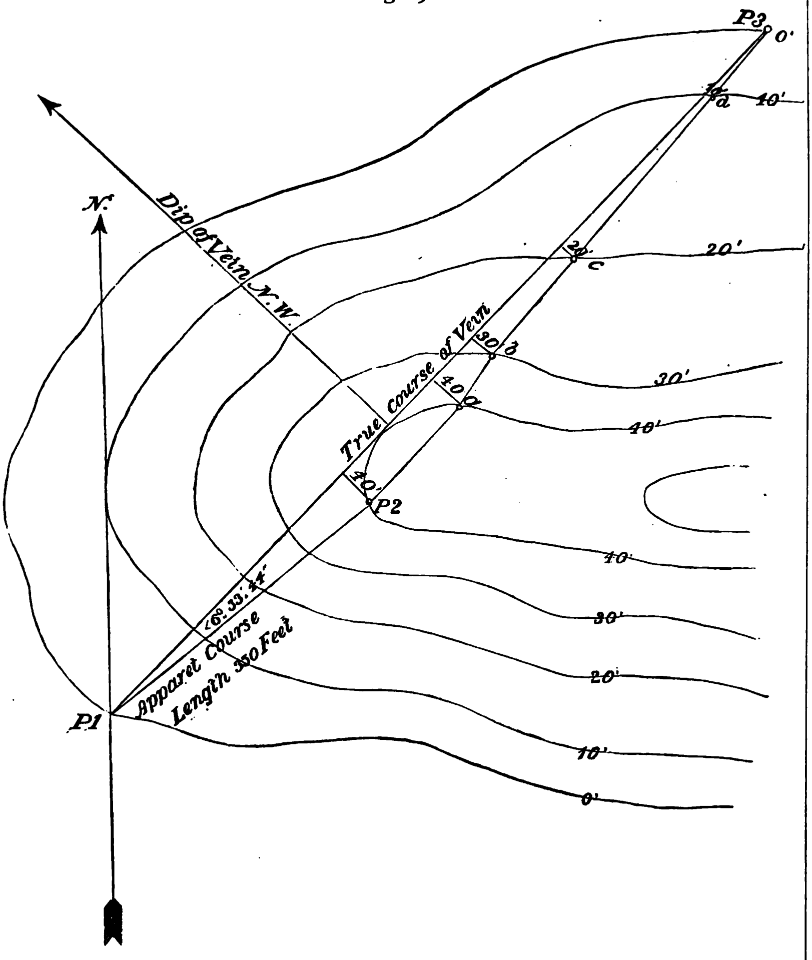


As Dist. from P 1 to P 2 Hyp., 350′ Ar. Comp., -	=	7.4559320
To Perpendicular, 40′ - - - - -	=	1.6020600
So is Radius, - - - - - -	=	10.0000000
To Sine 6° 33′ 44″ (after rejecting 10), -	=	9.0579920

Which is the angle to be laid off to the westward to give the true horizontal course of the vein.

In Fig. No. 9, ten feet of perpendicularity are represented between the lines of contour, or curve lines:

Fig. 9.



To carry out the illustration still farther, the line of the true course of the vein is shown as produced across the hill, as far as P 3, which is upon the same level with P 1, and it is assumed that the vein has been exposed on the surface at *a*, whose elevation is 40 feet; at *b*, height 30 feet; *c*, 20 feet; and *d*, at a height of 10 feet above points P 1 and P 3. If stakes should be set up at these

different points, they would be shown upon a curved line (as before stated) owing to the dip of the vein, which will outcrop to the eastward or westward of the true line in proportion to the elevation or depression of the surface. Where the surface at any point on the lode is higher than at P 1, the throw will be proportionally great to the eastward; if it should be lower, the same stratum will show to the westward, the divergence of the several points from the true line being proportional to their elevation or depression above or below the datum of P 1. It is essential to the proper development of a mine that the correct bearing of the vein be determined, for all of the principal working shafts should be sunk at right angles to its course, and besides which, its course, position, and dip, should be accurately laid down upon a plat of the property between the boundary lines of the location, so that the extent of the property contained in the vein can be exhibited with approximate exactness; to do which, the points and angles of its intersection with the boundaries must be made by careful measurement.

In localities where the dip of the geological formation is less than about thirty-five degrees from the vertical, the difficulty of making a survey with an ordinary transit instrument is apparent, for unless the standards to the telescope should be made of such a height as to endanger the stability of the instrument, it would be impossible to obtain a line of sight upon such an angle, by reason of the intervention of the horizontal limb, and an angle read by means of a vertical telescope and limb attached to the side, is eccentric with the angles determined by the horizontal limb, so that except by actual measurement from the centre of the horizontal telescope, which is in the vertical plane of the instrument, to the centre of the vertical telescope, and making a correction for the difference, an accurate survey cannot be obtained. An ingenious attempt to overcome this difficulty has been made by the adoption of two targets being supplied to the rod planted to be observed to, but there is always liability to error when using any points of sight which are not observed to as centres. In order to overcome this difficulty and others incident to such a survey, the writer, with the assistance of a friend, improvised an instrument, and accompaniments, which were found to be well adapted to the performance of the work; a riding telescope was saddled upon the telescope proper, the cross hairs of both of which were adjusted to coincide with each other; by the

super-elevation of this telescope the intervention of the horizontal limb was obviated when taking a vertical angle, as it was thrown forward to such a distance as to enable the observer to sight at any object which was at an angle of not less than seven degrees from the vertical. The direction of such a line of sight was correct in its relation to any other points of the survey, and the measurement of the hypothenuse of a right-angled triangle being made from the axis of the instrument to the point observed, would by computation of the same give the length of the base practically correct; the axis of the instrument was perforated in a similar manner to astronomical instruments, so that the telescope could be illuminated, and a reflector was introduced so that the intensity of light thrown upon the cross hairs could be increased or diminished at the pleasure of the observer. It was supplied with two trivets and three telescopic tripods, for use as the exigencies of the case demanded, and for each of which plumb-bobs were provided. Also, with two lamps capable of being set upon the leveling screws attached to the tripods and trivets which could be leveled approximately by means of a universal level carried by the assistant, and as the wicks of the lamps were made to burn precisely at the height of the axis of the instrument, any observation made to them when set up as a back or fore sight, was made to the exact point of observation. The use of lamps is preferable to that of candles, for it frequently happens that quite a lapse of time occurs between the time of observing at the top of a shaft, before the course is measured, and the instrument is in readiness to be set up at the bottom for taking the back sight, during which the candle will have burned down considerably, particularly in a well ventilated mine, where the draught is good; and also by the use of three tripods, the instrument is detached from the tripod which is left standing at the top for a back sight, and is readily transferred and set up at the second point at the bottom with exactness, as the plate of the screws has been leveled to receive it upon the second tripod in its correct position for taking the back sight, the plumb-line being left attached to the instrument for that purpose. Trivets are particularly useful in shafts where a ridge occurs in the back or foot wall, for it frequently happens that a line of sight cannot be obtained from one level to another of a shaft, by reason of such obstruction, and by spiking on a cleat of wood to a road bed or a ladder which is well

stayed by braces, it is possible to effect a reading in this manner with much greater ease than by the use of tripods, which in some extreme cases it would be impracticable to use. As the working of a mine progresses however, and the use of trams or skips as they are termed, supplant the use of the kibble or bucket, these ridges or backs are *taken up*, and the line of the whole shaft is brought to as perfect a plane as possible. The chain used for measuring down the shafts should be constructed of the finest steel, of 100 feet in length, and links of 6 inches. Its lightness renders a correct measurement of the line from the axis of the instrument to the point of sight possible, as by giving it a proper tension the catenary can be reduced to an approximate minimum. The vertical height of the axis of the instrument, above or underneath the level of the points of survey, are always to be measured carefully and taken into account at both ends of the line of sight, when measuring the hypothenuse of a vertical triangle, to be added or subtracted in a proper manner, to or from the vertical height as computed from the obtained data. The pins used for such kind of survey should be made of drawn steel, with very small eyes for the tags, the greatest diameter of the metal being at a distance of about four inches from the point to which the thickest part tapers. Such pins can often be used as plumb-bobs when measuring fractional parts of a chain on declivities. The line of the lode having been determined in reference to the boundaries of the location, a base should be laid out upon the surface, having common reference thereto. In selecting this base of operations, which, if practicable, may be in one continuous line, or otherwise in a series of lines, the angles between and distances of which are carefully measured, care should be taken to set the points involved at such distances, and in such positions as to insure their not being removed or covered by the material taken out of the shafts, or by the mechanical appliances which are used in the development of such enterprises; all the points of the survey should be well secured, either by driving wooden stakes into the surface soil firmly, and to such a depth as will insure their being kept in place; or where rock outcrops, a hole should be drilled into it and a permanent rod or bar of iron should be inserted. A worn out drill let into the rock and referred to some permanent object, so that it can be found and identified if covered with debris, is suitable for such a mark. It frequently

happens that the timbering of a shaft at the surface is required to be raised, and the original points of a survey in such case are obliterated. Resort may then be had to the reference marks. From the course or courses comprising this base, a shaft or shafts can be sunk at right angles to the line of the lode.

It is not always practicable, however, to set the instrument exactly on the center line of a shaft, either at the surface or underground, even if the shafts are sunk perpendicularly to the course of the lode; the line of observation therefore is not arbitrary, but can be selected for use at the most convenient points which are practicable; by measurement from these points the center of the shaft can be determined. As soon as the shafts have been sunk to the required depth of the first or second level, due allowance having been made for the drainage of the drifts, the best method to adopt in surveying them in connection with the drifts is, to set up the instrument back of the collar beam of the shaft, and mark the point exactly under the plumb-bob of the instrument, with a spike well driven into the timber or flooring of the plat, reference to the same being made by measurement to the corners of the shaft house or covering, if it is already built. It may be necessary to throw a stout plank across the mouth of the shaft, upon which to place one of the legs of the tripod. The assistant having gone down to the first level and selected a point, and set up the forward tripod, with a lamp affixed and leveled as before described, which is in view from the instrument at top; the sight having been taken, the telescope should then be turned over in the Y's (or transited), and an interpolation point should be marked and secured upon the line of the base; this projected line is then made up of two parts, the one part being the horizontal measurement from the interpolation point on the base to the point of observation at the top of the shaft, and from which its course can be determined; the other part being the computed length of the base of a vertical right-angled triangle, having given the hypothenuse (by measurement down the shaft from the axis of the instrument to the point observed to) and the vertical angle, to be added to, or subtracted from the line of projection from the base, according as the dip of the lode is towards, or away from the base; this can be traversed in one course, and the course can be identified at any future time by the marks set as described. Having taken the down sight and measured the line, the tripod is left standing

with the plumb-bob attached, and the instrument is removed to the lower point and placed upon the tripod which has been observed to, and is in readiness for its reception. The drifts or galleries having been commenced on either side of the shaft, a back sight is first taken to the point at the surface, and horizontal angles are then measured to points which have been previously selected for use in the survey of the drifts, the readings to these points being in relation to the meridian established for the general survey.

If it has been necessary to construct a platform upon which to set the instrument, and which would interfere with the hoisting of the material during the time of the survey, and which could therefore be only a temporary structure, a hole should be drilled precisely over the point of observation, into which a wooden plug should be inserted, and a flat-headed nail then driven into the plug, the nail-head being pierced so that the line of the plummet can be threaded through and suspended over the point in future. In order to avoid the trouble of laying a platform across the shaft in future, the extremities of the first courses to the right and left, one on either side of the shaft should be visible from each other (the work having been laid out and the holes bored, and plugs inserted previous to the time of the survey), and at the first time of setting up the instrument, readings and measurements should be taken to both of the points, and the course between the outer points determined by setting up the instrument at one of them upon the back sight of the first reading, and observing to the other on the opposite side of the shaft. The survey of the drifts is made in a similar manner to an overground survey. But while the instrument is set up for the first time at foot of shaft on the first level, take the sight and measurement down to the second level if it is already sunk. When at the second level, a plumb bob, pendant from the plug over point in shaft at first level, will give a back sight, as taken from the second level after the platform is removed. If the telescope of the instrument is provided with an attached spirit level, benches or reference marks should be chiseled into the walls, for future reference, in addition to the actual measurement of the vertical distance from the plug overhead to the axis of the instrument, as by this means a greater degree of accuracy can be attained.

In order to close and test the accuracy of the work, lines of sight

and measurement must be taken down each shaft, as has been described in connection with the survey through the drifts, and the co-ordinates of all the points involved in both the surface and underground surveys, must be computed and verified through the connections of the lines down the shafts.

In order to make a correct exhibition of the amount of excavation which has been done, frequent measurements must be made from the lines of survey to the walls on either side, and where stoping (or actual mining) has commenced, the heights of the stopes must be noted; the width of the drifts can then be shown upon a horizontal plan of the mine, and the quantity of material which has been taken out can be exhibited upon a longitudinal profile plan of the whole mine. As a rule it is better to drive a gallery from the pumping shaft of a mine towards the next winze or shaft, particularly for the first two or three levels, for the reason that where surface-water is introduced it runs away from the miners; it is often necessary, however, to drift both ways and connect midway between the shafts; when such is the case the water follows the miners in the higher portion of the drift, and cannot find an outlet except by the use of a pump temporarily placed for the purpose; it is then necessary to be careful that a proper fall be given to the floor of the drift, as the miners will often attempt to avoid the collection of water by giving an upward inclination to the floor, when to do the work properly it should have a downward inclination.

In the survey of a true fissure vein which crosses the general geological formation of a district of country, a perplexity often arises, through the verticality of the vein. In many cases such fissures are nearly or quite vertical, and any base at a lower level which is produced from a survey on the surface, is necessarily short, the width of a wide working shaft seldom exceeding ten feet; consequently, if an attempt should be made to obtain a base, in length the full width of the shaft, by dropping two plumb lines, taking into account the probabilities of error in the manipulation of the instrument and fixing the points as extremities of the base, the result derived through such a basis would be extremely doubtful; for any error introduced in the determination of an angle from so short a base, would be carried through the subsequent courses of the survey. A better method to adopt in making such a survey